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Review
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LONG-TERM MECHANICAL CIRCULATORY SUPPORT: SURGICAL TECHNIQUES

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Summary

Long-term mechanical circulatory support has become a valid treatment option for end stage heart failure. In selected patients' cases, this therapeutic option has been proven to improve survival, both as a bridge to transplant and as a destination therapy. In this article, we address implantation technique, strategies to prevent excessive bleeding, right heart failure, and driveline and pocket infection.

Key words: heart failure; mechanical circulatory support; surgical technique

Devices

Left ventricular assist devices (LVADs) are classified as either pulsatile or non-pulsatile (continuous), based on the nature of the flow they produce. The pulsatile pumps have a mechanical pusher plate or sac that propels blood mechanically or pneumatically, whereas continuous flow pumps are rotary devices that establish continuous flow. Furthermore, continuous flow pumps are either centrifugal or axial flow, where centrifugal pumps utilize a rotating disk that spins blood in a circular motion to create centrifugal force to pump blood; an axial flow pump consists of a spinning rotor that propels blood alongside the native circulation.

Pulsatile devices, such as Thoratec VAD system, allow left, right, or bi-ventricular assistance to patients with end stage heart failure. The VAD are prosthetic ventricles, which are composed of blood sacs inside a hard plastic casing. A pressure/vacuum system allows the air to enter the casing around the blood sac. This expansion and contraction of the air sacs allows the VAD to fill and eject blood, and provides the body with blood flow similar to that of the native heart. It has been FDA-approved both as a bridge-to-transplant therapy and for post-cardiotomy recovery from

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open-heart surgery. Thoractec pVAD is a paracorporeal device – the pump chamber is outside the body, thus allowing the use on patients of small body size.

Most of the currently widely implanted devices are the axial-flow rotary devices (such as Thoratec Heartmate II; BerlinHeart INCOR; MicroMed DeBakey VAD; HeartWare HVAD) that possess several advantages over the older devices, including their small size, ease of implant, durability and silent operation. However, since the device implant still requires open-heart surgery and the use of the cardiopulmonary bypass, patients may potentially develop complications related to the surgery.

Surgical technique

Although there is a whole range of different devices available on the market, the operative technique has been standardized with the following steps: mediastinal exposure with the creation of the device pocket; outflow graft anastomosis to the ascending aorta; placement of device inflow cannula at the left ventricular apex; de-airing of the device; and device start followed by weaning from cardiopulmonary bypass (CPB) support.

The patient is prepared for open-heart cardiopulmonary bypass surgery as usual. The sternum is opened, and prior to heparinization, a pre-peritoneal LVAD pocket is created in the left upper quadrant. We try to develop the plane above the posterior rectus sheet and to size the pocket according to the device mannequin. It is of utmost importance to perform meticulous pocket hemostasis, because the pocket will be inaccessible after the definitive pump placement.

To minimize the bypass time, it is possible to perform aortic anastomosis first with the use of aortic side-biting clamp. The graft is precloted, measured, trimmed, and sewn using 4-0 Prolene sutures with additional reinforcing Teflon strips. To prevent additional bleeding, fibrin glue is generously applied over the entire anastomosis line.

The heart is cannulated in the usual fashion, via the aorta and a single atrial venous cannula. CPB is instituted to allow the placement of the left ventricular apical inflow cannula. We tend to do it in normothermia on a beating heart, with the operating field being flooded with carbon dioxide. The left ventricular vent is placed via the right superior pulmonary vein to both maintain a dry operative field and additionally help de-airing the heart.

The heart is lifted and a specialized coring knife is used to create the apical core. Exact site and direction of coring should be carefully selected to avoid deviation into the septum. Like in all axial-flow pumps, there is a risk of generating negative intraventricular pressure and collapsing the ventricle. Therefore, inflow cannula positioning and ventricular preload are crucial to avoid potential suction events. Trabeculations that may impinge on the cannula should be excised and possible

mural thrombi completely removed. Afterwards, 12-15 braided polypropylene 2-0 sutures with medium-sized Teflon pledgets are equally spaced around the ventricular opening, passed through the sewing ring of the inflow cuff, and tied. Additional running Prolene 3-0 suture with circular Teflon strip and abundant fibrin glue can be used for the reinforcement of anastomosis. The cannula is brought down to the ventricle, secured to inflow cuff and attached to the LVAD body.

The LVAD driveline is passed through the abdominal rectus muscle and subcutaneous tissue using the appropriate stylet to the skin of the upper abdomen. We routinely try to lengthen the subcutaneous part of the driveline by passing it first through the auxiliary skin incision at the right upper quadrant, and afterwards to the final exit spot, slightly to the left from the median line and above the patient's belt line. By this maneuver, the potential route for infection spread from the driveline exit wound to the device pocket is significantly extended.

The heart is allowed to fill with blood and the device is de-aired through its outflow part. The previously de-aired outflow graft is then attached and secured to the device body. An additional venting hole is placed in the outflow graft. The complete evacuation of air is confirmed with transesophageal echocardiography and the device is started. The patient is then weaned from the CPB.

We routinely place a Gore-tex pericardial membrane over the anterior mediastinal structures and secure it to the pericardial edges to minimize the risk of injury during the planned reoperative sternotomy. Chest tubes are placed in the opened pleural cavities and in the mediastinum – next to the apical inflow cannula and LVAD pocket, and retrosternally, over the pericardial membrane. After the hemostasis is achieved, the chest is closed in the standard fashion.

Bleeding prevention

Excessive mediastinal bleeding is common after mechanical circulatory support device implantation, occurring in up to 40% of patients; it can lead to massive transfusions and re-exploration. Many risk factors predispose excessive bleeding in this subset of patients, including the compromised nutritional status and hepatic dysfunction due to chronic heart failure; extensive surgical dissection; reoperations; prolonged cardiopulmonary bypass; and coagulopathy, due to interactions between the circulating blood and the artificial surfaces.

Therefore, a special attention should be paid to the meticulous hemostasis of all surfaces. Some of the procedural steps, such as pocket creation and driveline tunneling, should be done prior to the heparin administration. We also routinely use a cell saver for intraoperative blood salvage, administer tranexamic acid in optimal doses to efficiently inhibit fibrinolysis, and use fibrin glue to reinforce suture lines.

Thromboelastography is routinely used both preoperatively and after the protamine administration to guide the possible coagulopathy treatment.

Right ventricular failure prevention

Right ventricular failure is a dreaded complication after the VAD implantation, with an extremely high mortality (up to 40%). Some intraoperative measures also contribute to the right ventricular failure prevention. Mean arterial perfusion pressure during implantation should be kept above a mean of 70 mmHg to provide the RV protection. Cardioplegic arrest should be used only in selected cases. The left ventricle, the assist device, the outflow graft and the ascending aorta should be meticulously de-aired to avoid a possible air embolization of right coronary artery. Excessive bleeding and massive transfusions impair the right ventricular function; it should therefore be avoided at all costs. Finally, left ventricular assist device speed should be adjusted to prevent an excessive shifting of the interventricular septum to the left side, which regularly impairs the right ventricular function.

Infection control

Clinical experience has shown that the LVAD infection rates can be minimized by optimizing the implant techniques and wound care; appropriate antibiotic prophylaxis; avoiding infections in indwelling catheters; maximizing patients' nutritional status; and optimizing glycemic control. There are several additional intraoperative and postoperative considerations that are important for infection control. The size of the preperitoneal device pocket should be minimized, whilst the length of the driveline passed through the abdominal wall muscle should be maximized. The sterility of all implantable materials should be vigorously monitored, while the number of people circulating the operating room should be limited to the necessary minimum. It is of utmost importance to immobilize the percutaneous driveline exit site, possibly by using an additional 2-point holder or a stabilization belt. Postoperatively, the exit wound dressing should be changed daily through the initial weeks, and subsequently on a 2- or a 3-day basis. The wound should be cared with chlorhexidine. Any signs of exit wound infection should be aggressively treated by daily re-dressing using hydrogen peroxide and povidone-iodine, combined with a targeted antibiotic therapy.

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Sažetak

Dugotrajna mehanička potpora cirkulaciji: kirurške tehnike

Dugotrajna mehanička potpora cirkulaciji postala je provjerena metoda u liječenju završne faze srčanog zatajenja. Kod odabranih bolesnika, dokazano je da poboljšava preživljenje, bilo kao potpora do transplantacije ili destinacijske terapije. U članku opisujemo tehnike ugradnje, strategije u cilju smanjenja prekomjernog krvarenja, zatajenja desnog srca te infekcije oko mjesta izlaska kabela za napajanje.

Ključne riječi: zatajenje srca; mehanička potpora cirkulaciji; kirurška tehnika